

LDEF and Other Lessons Learned

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Outline

LDEF Background

Results from LDEF

Molecular Contamination Studies

Materials Performance Summary

Comparisons with other flight results

EOIM III re-flight of selected materials

Comstar radiators

Rogues Gallery – contamination examples

Additional opportunities

Summary



NASA Post-Flight photo of LDEF

The Long Duration Exposure Facility (LDEF)

30' x 14' (diameter), 21,000+ lb spacecraft

Deployed from Space Shuttle, April 1984

Retrieved by Space Shuttle, January 1990

69 month flight in LEO, 28.5° inclination

Initial altitude 257 nmi

Retrieval altitude 179 nmi

Fixed orientation, gravity gradient stabilized

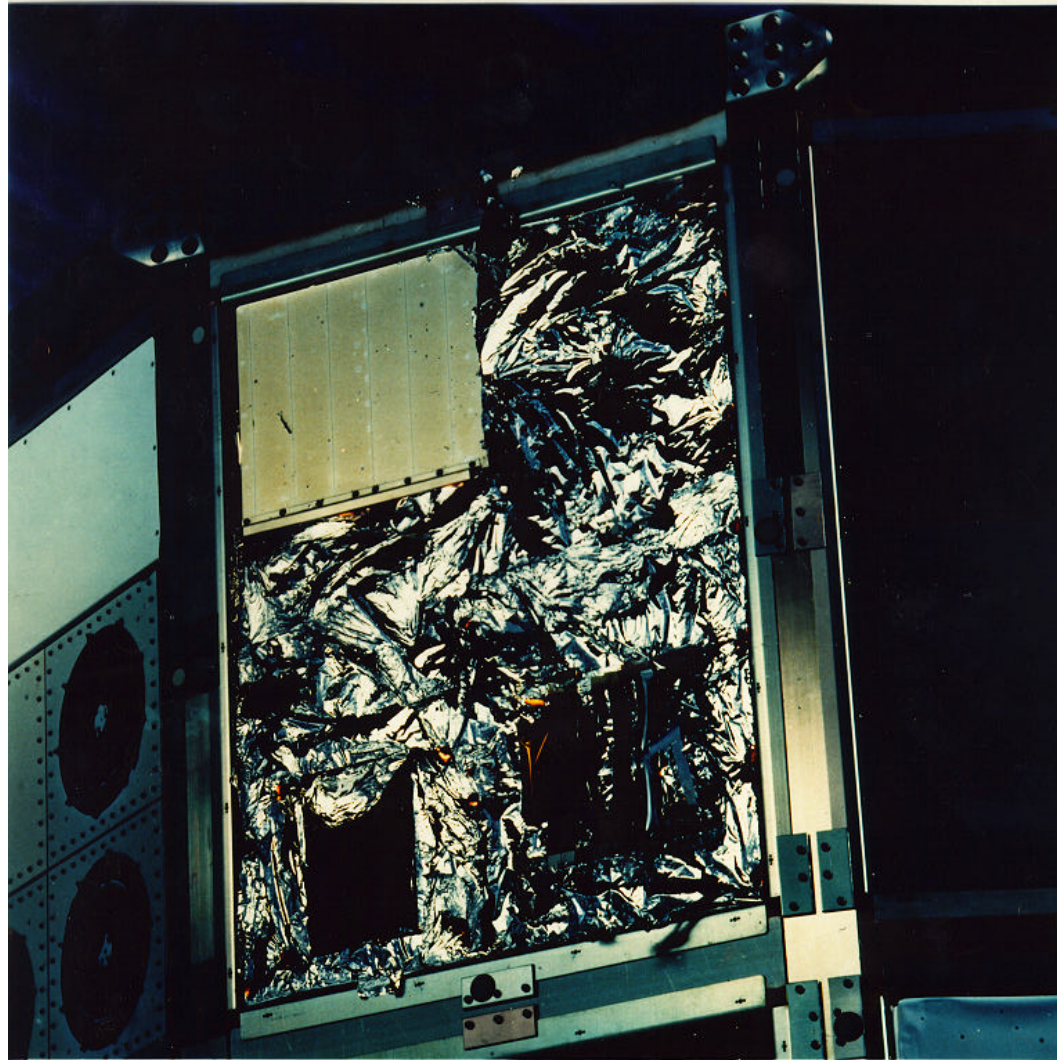
Exposure conditions ranged from solar min to solar max



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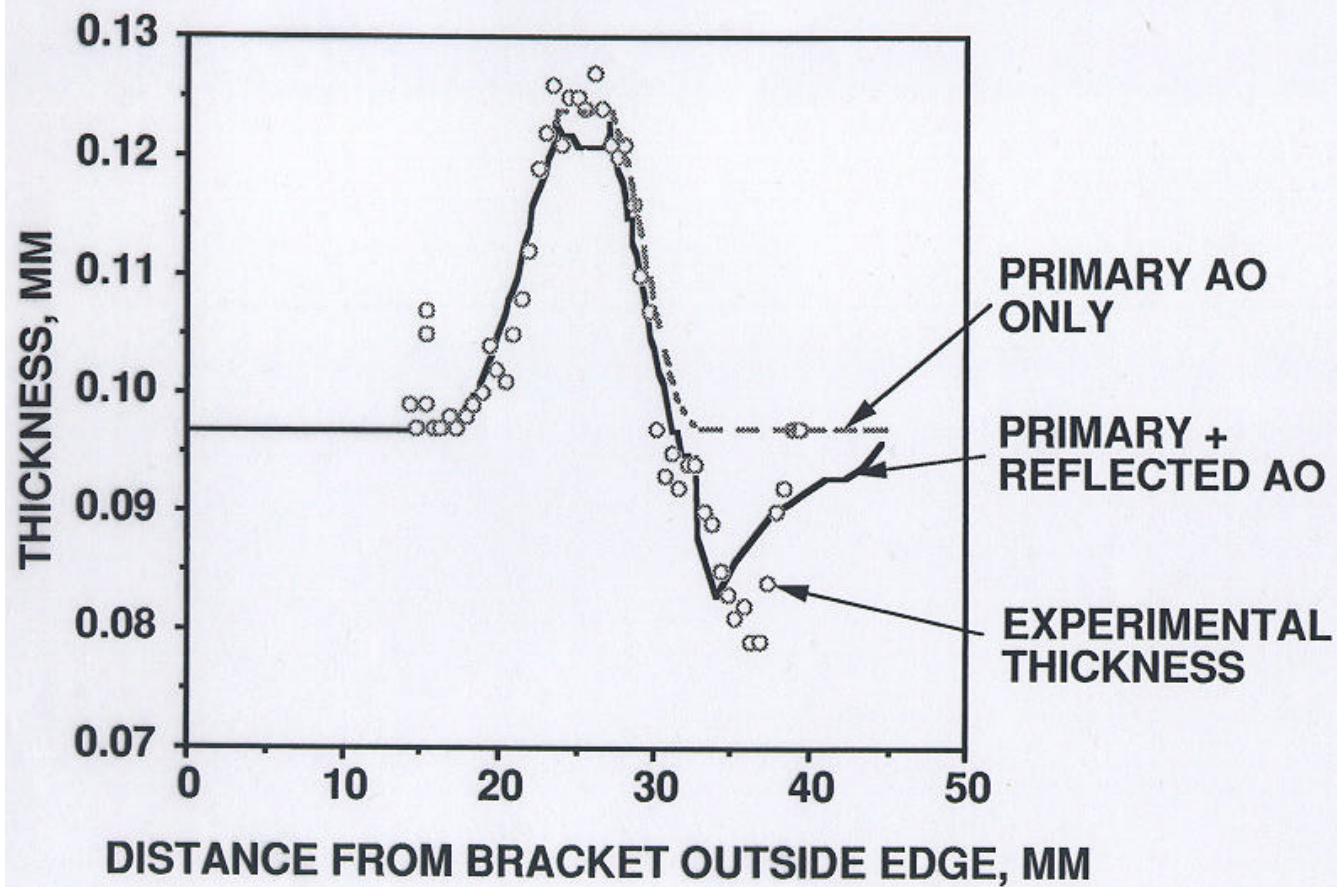


NASA On-orbit photo of tray F9 showing failed thermal control blanket



NASA Post-flight photo of tray F9

OBSERVED AND PREDICTED EROSION, FEP ANGLE BRACKET COVER, TRAY F9



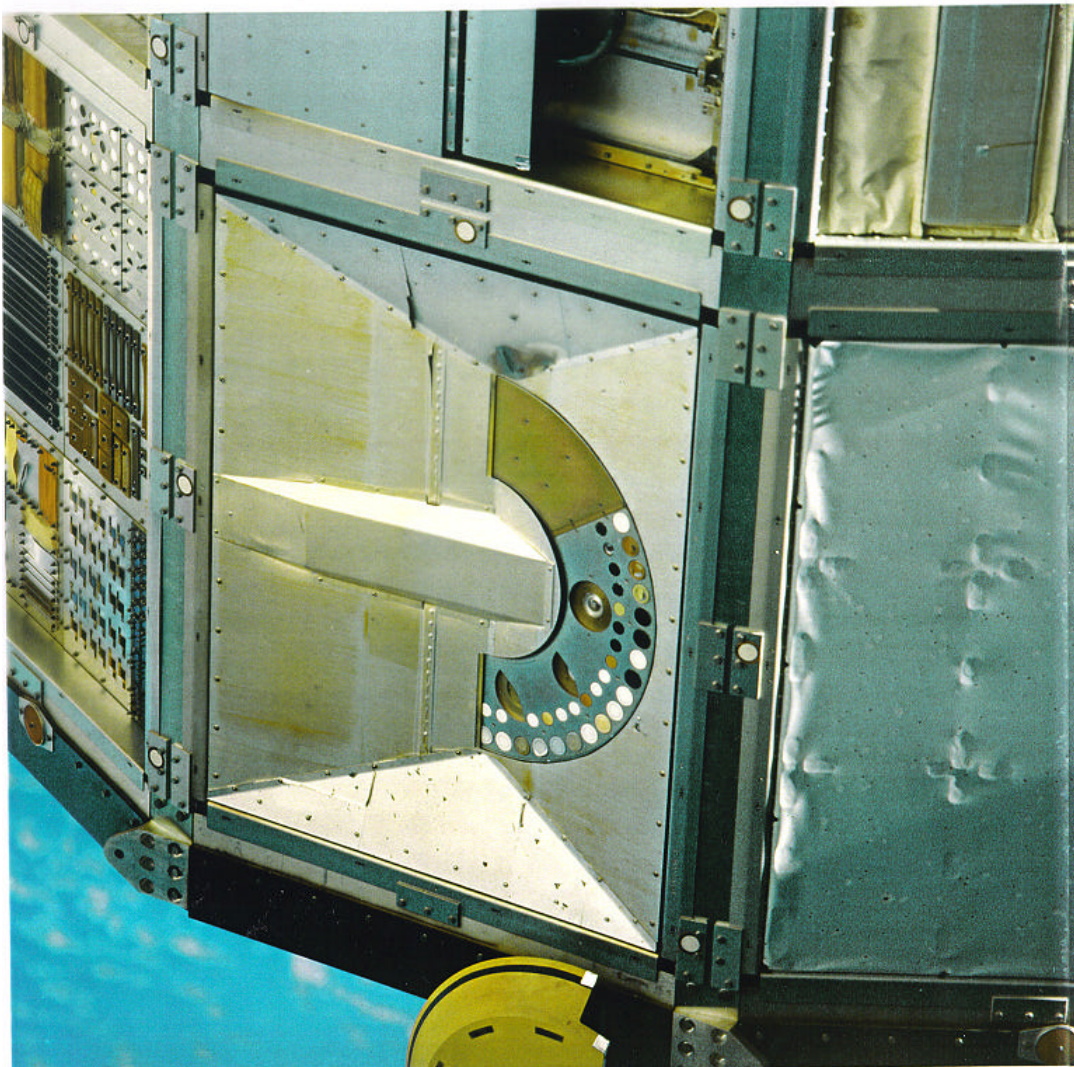
Pre-flight Influences

Application Technique of Adhesive Backed Ag/FEP

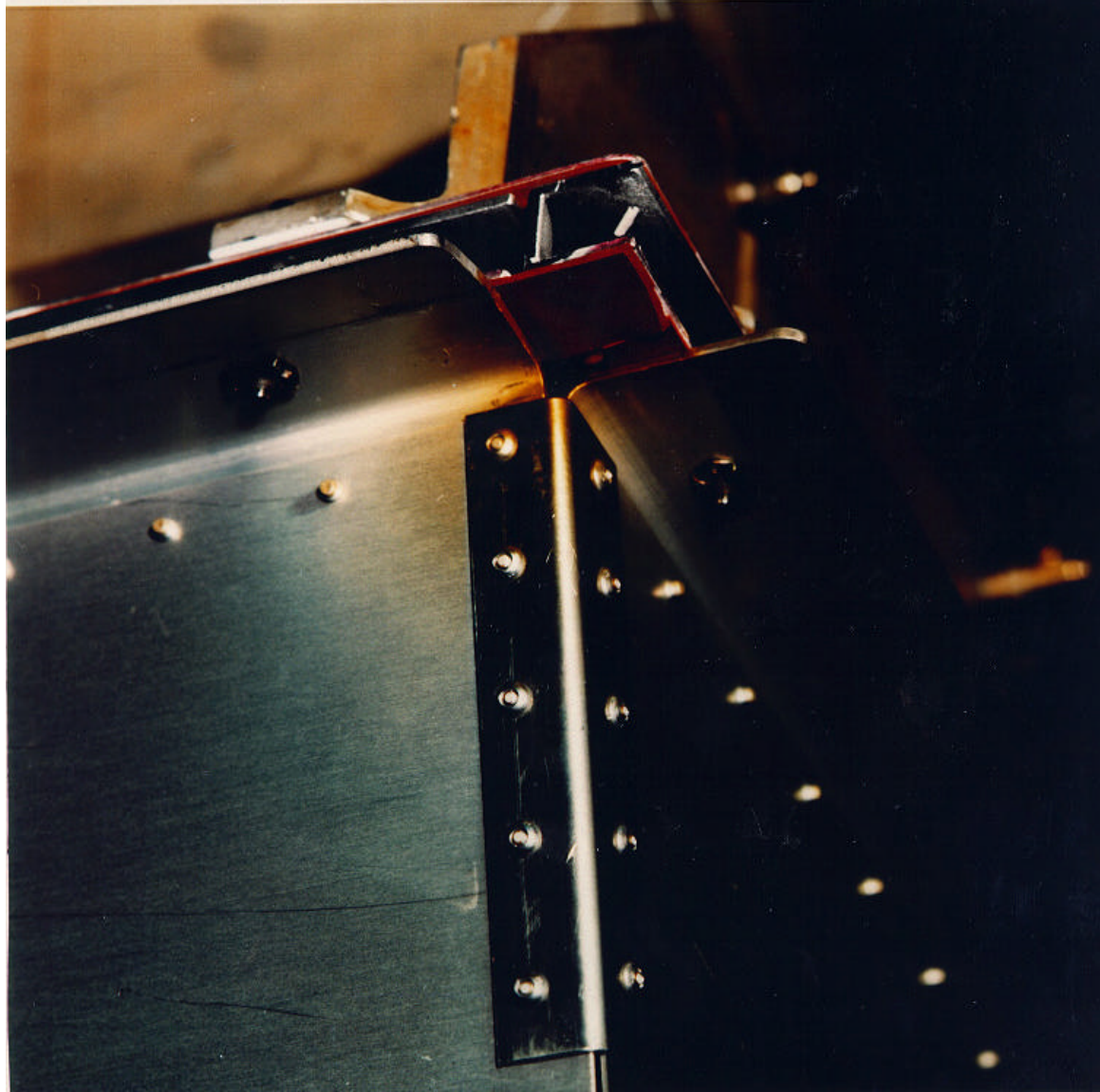
Use of high outgassing materials in contact with flight hardware

No stress relief of tape on NRL experiment

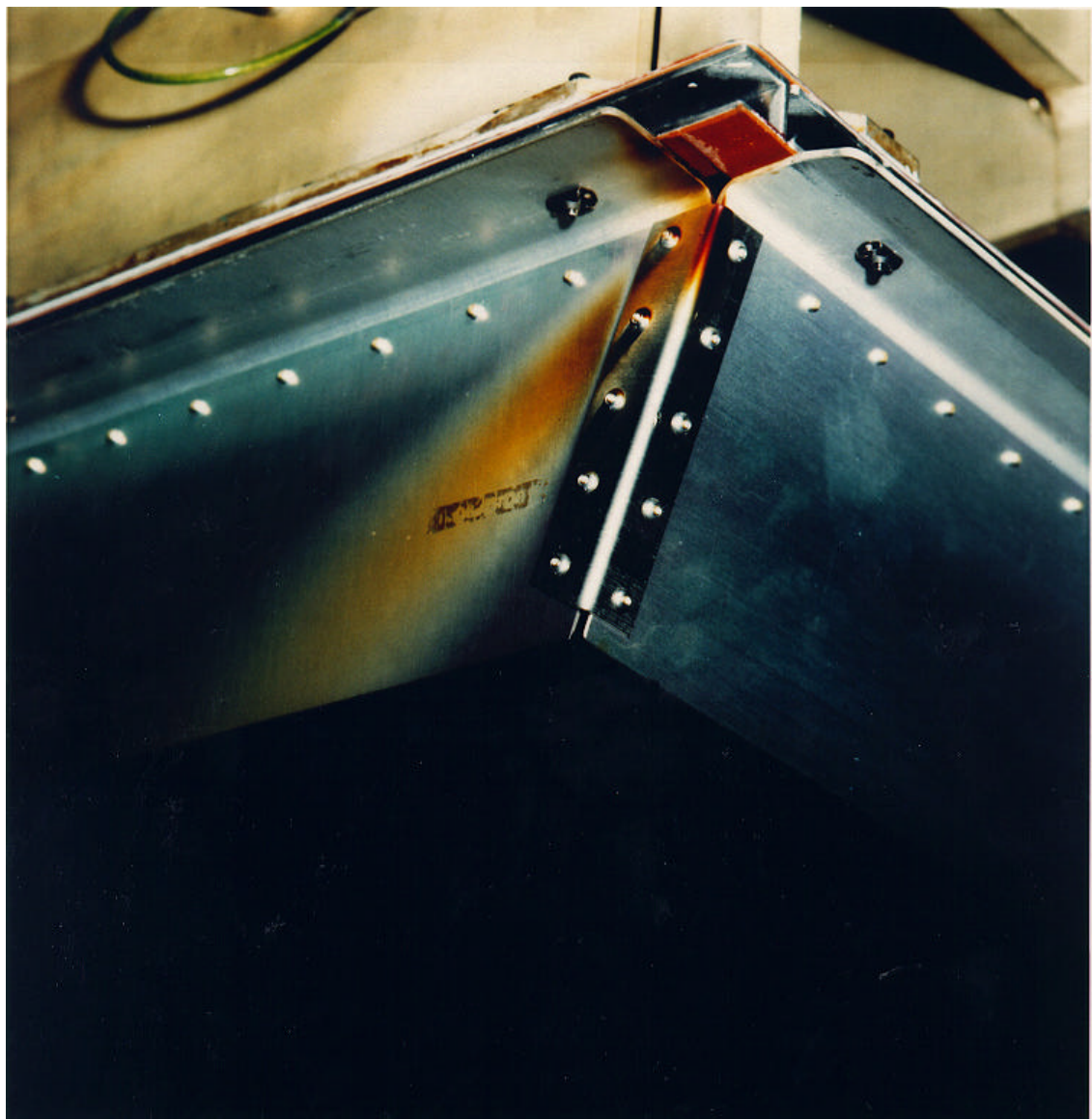
Handling of certain thermal control surfaces without gloves



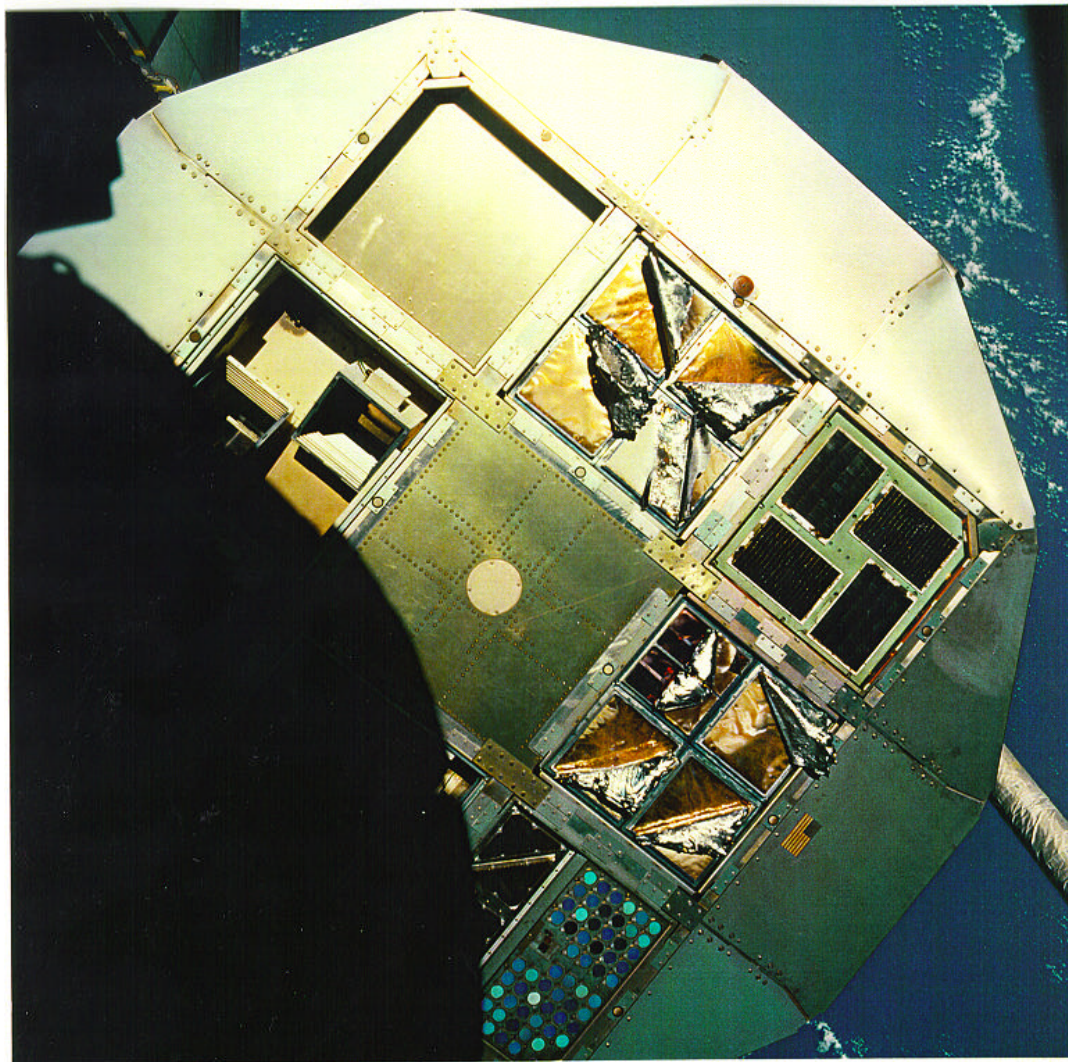
NASA On-orbit of tray A9



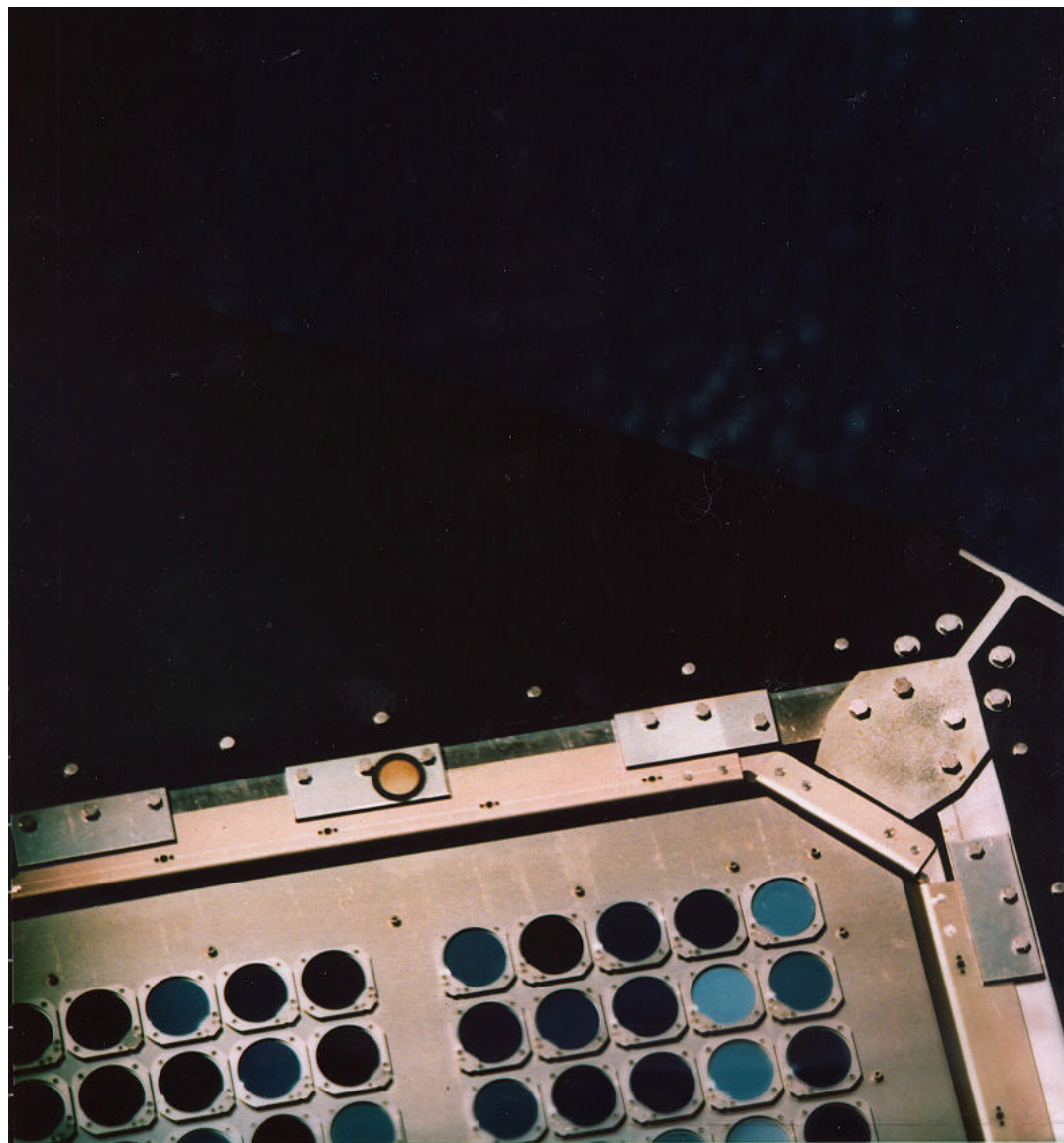
NASA Post-flight photo showing position of gasket relative to discoloration



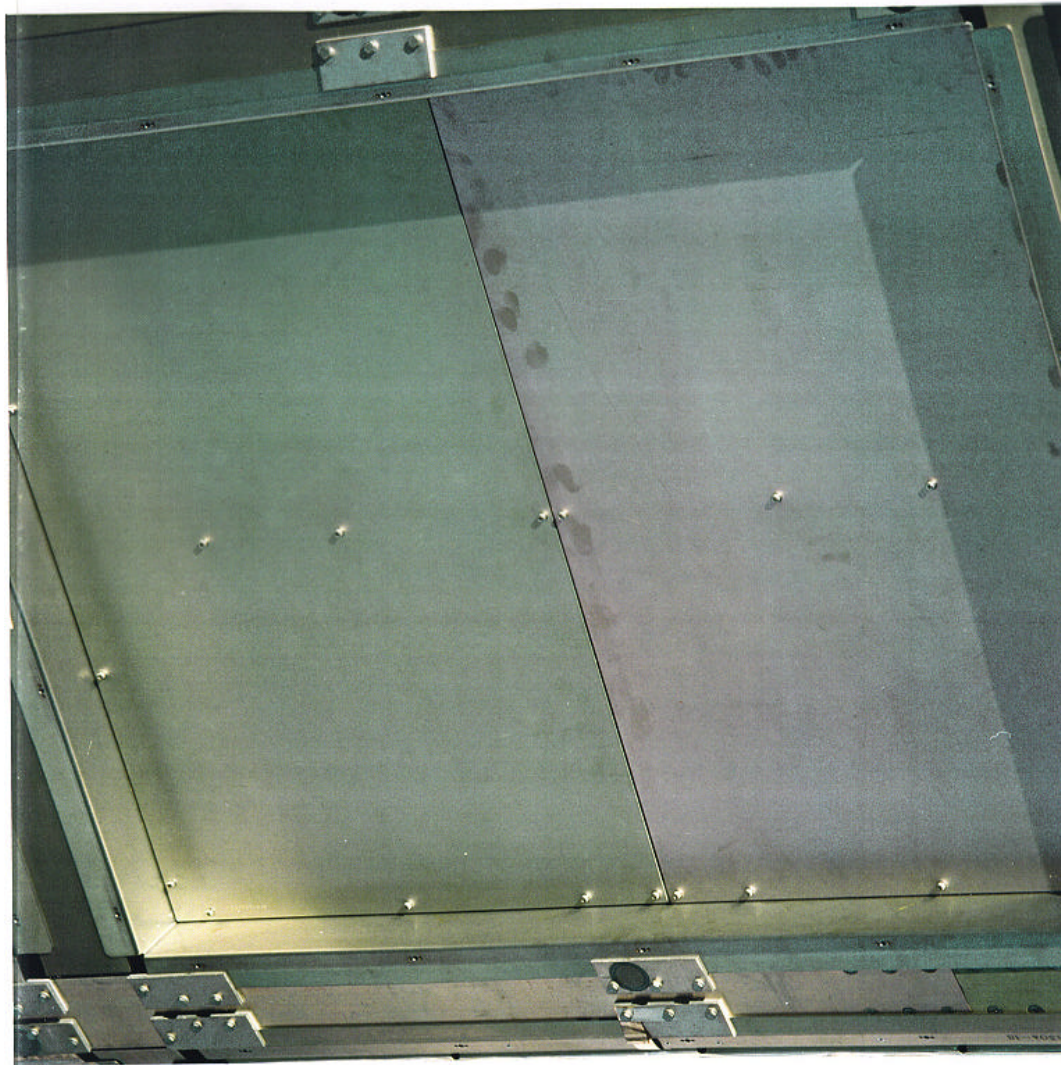
NASA Post-flight photo showing discoloration due to On-orbit exposure



NASA On-orbit photo showing failure of tape holding thermal control blankets on space end of LDEF



NASA On-orbit photo showing fingerprints on Earth-end thermal panel



NASA On-orbit photo of thermal panels showing fingerprints from pre-flight handling

Tray Clamp Bolt Heads

Orientation

**Bolt heads are flat surfaces raised slightly above LDEF tray surfaces
Essentially no view-factor to LDEF surfaces**

Deposition Sources

Exposure is line-of-sight to Space Shuttle payload bay on deployment and retrieval missions. Direct exposure to natural environments during free flight.

SILICON CONCENTRATION ON BOLT HEADS FROM AES PROFILES

| BOLT NUMBER | ANGLE degrees | AO FLUENCE atoms/cm ² | DEPTH AVERAGE CONCENTRATION silicon % | PROFILE DEPTH Angstroms | SILICON MASS g/cm ² |
|----------------|------------------|--|---|-------------------------------|--------------------------------------|
| H11-7a | 89 | 4.59E+20 | 6.79 | 84 | 1.32E-7 |
| A6-6c | 83 | 1.16E+21 | 3.56 | 108 | 0.89E-7 |
| E9-4c | 8 | 8.99E+21 | 5.64 | 84 | 1.10E-7 |
| D7-7a | 53 | 5.45E+21 | 7.07 | 108 | 1.38 E-7 |
| AVERAGES | | | 5.77 | 96 | 1.17E-7 |

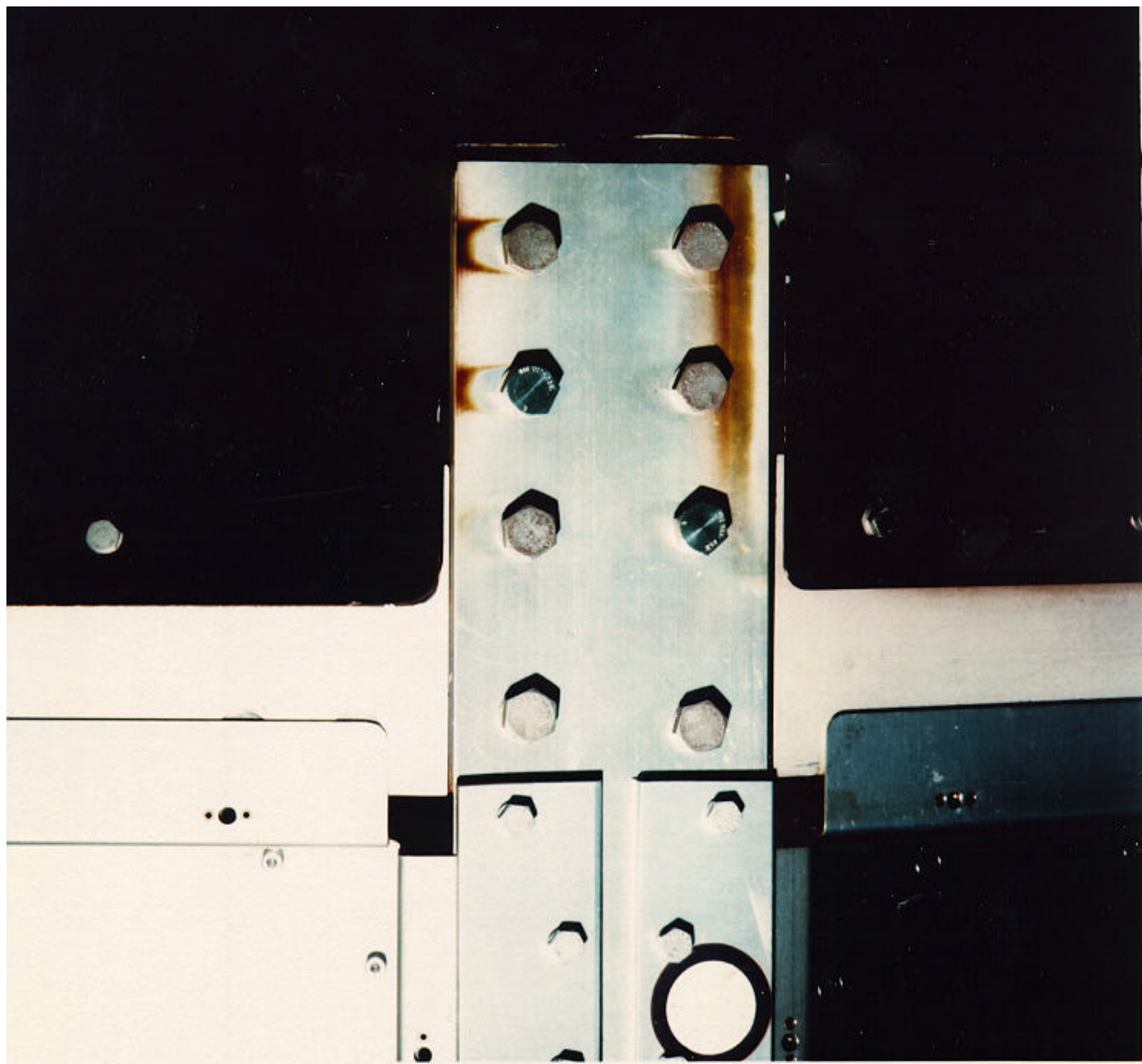
SILICON MASS

$$\text{SILICON MASS ON LDEF SURFACE} = (1.51\text{E}+6 \text{ cm}^2)(1.17\text{E}-7 \text{ g/cm}^2) = 0.18 \text{ g}$$

Contamination Patterns from Earth and Space End Interior Vents

Thick Deposits close to Vents 2-3 cm

Line-of-sight Depositions



NASA photo showing Discoloration around vents from LDEF interior with pattern disrupted by presence of bolts

Contamination Patterns on Longerons

Locations between A11-A12 and F11-F12

How are patterns to be explained

Deposit at Edges – Material outgassed from interior

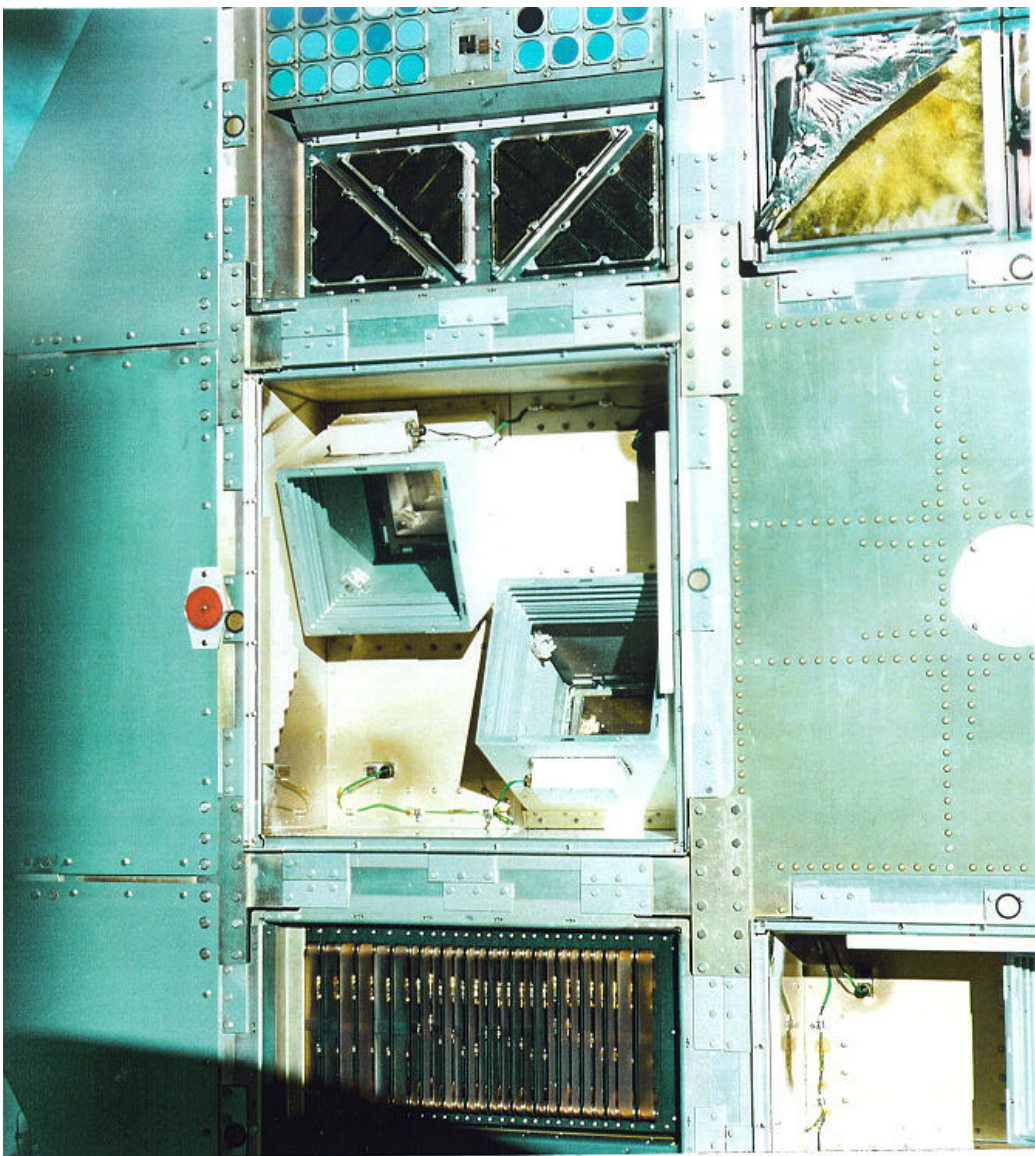
**Thicker toward end with vent
(not blocked by intercostal)**

Patterns around bolt heads

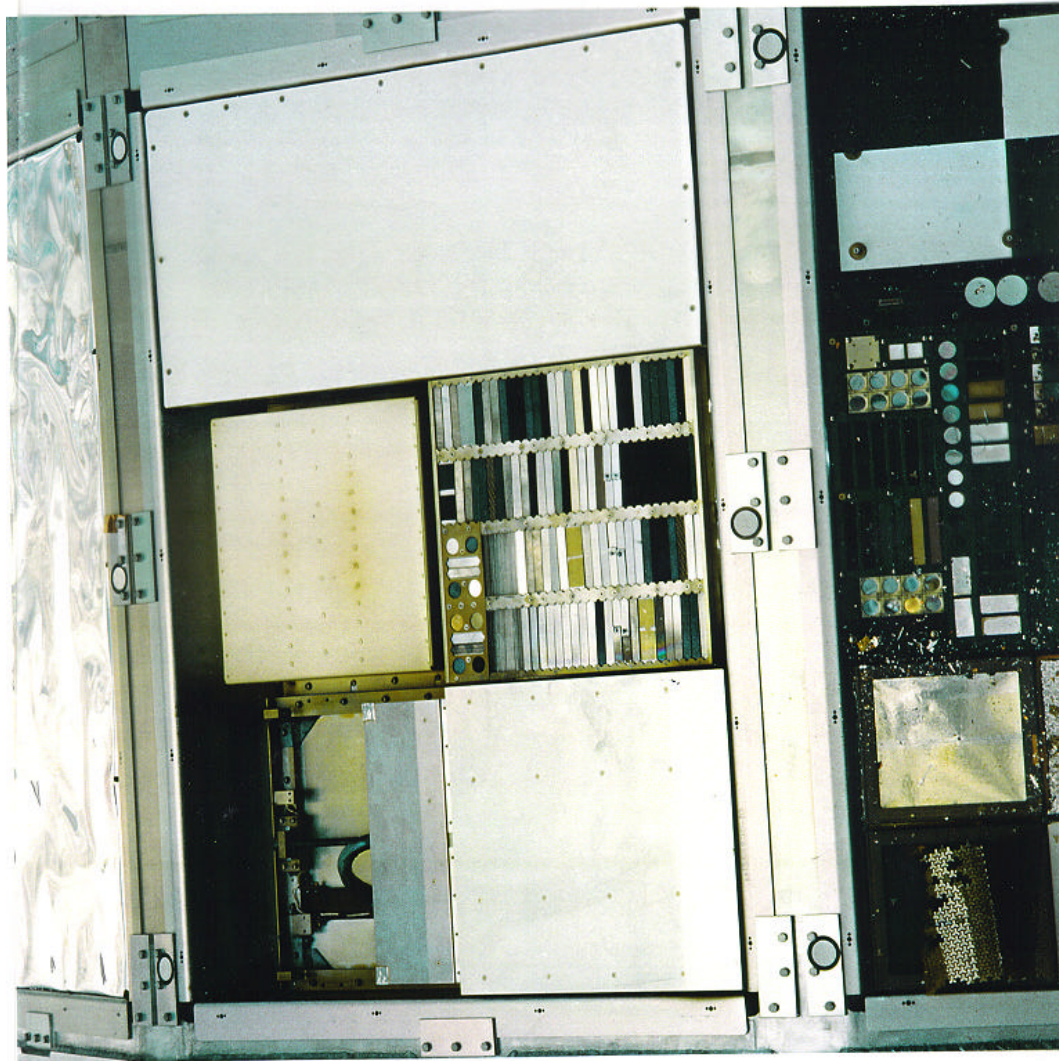
Si + Carbon?

Sunrise-sunset phenomenon?

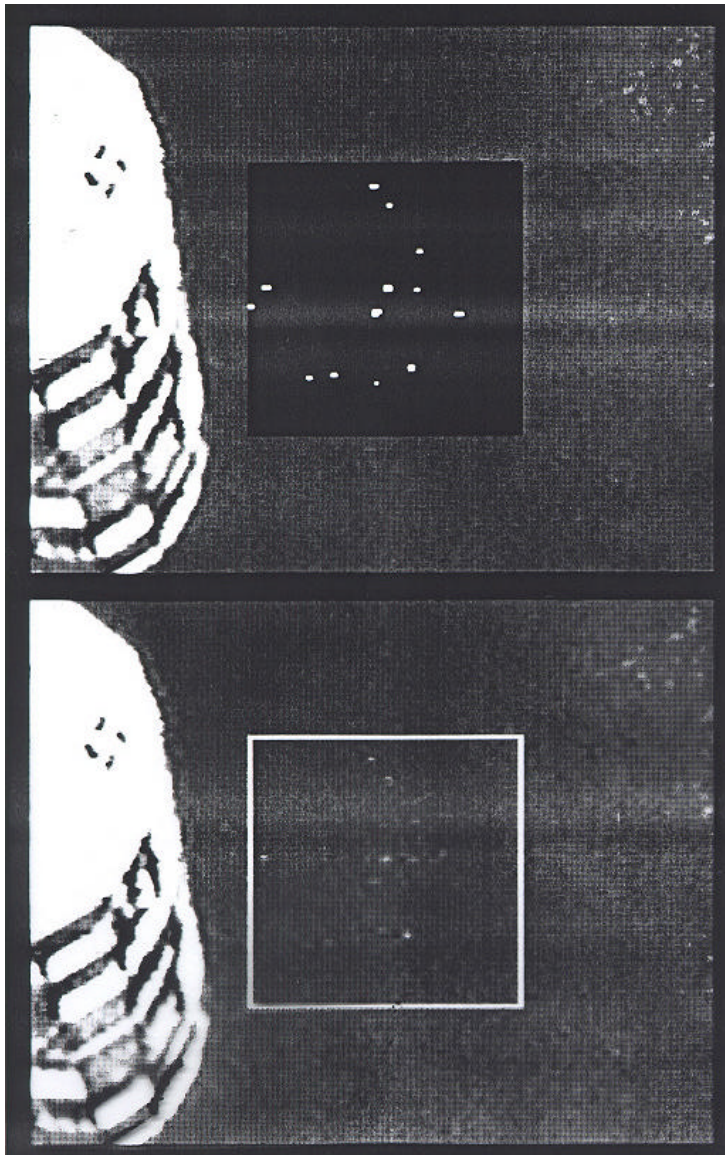
**Reflections? – AO removal of material between bolts (carbon based) +
photo-attachment by solar UV?**



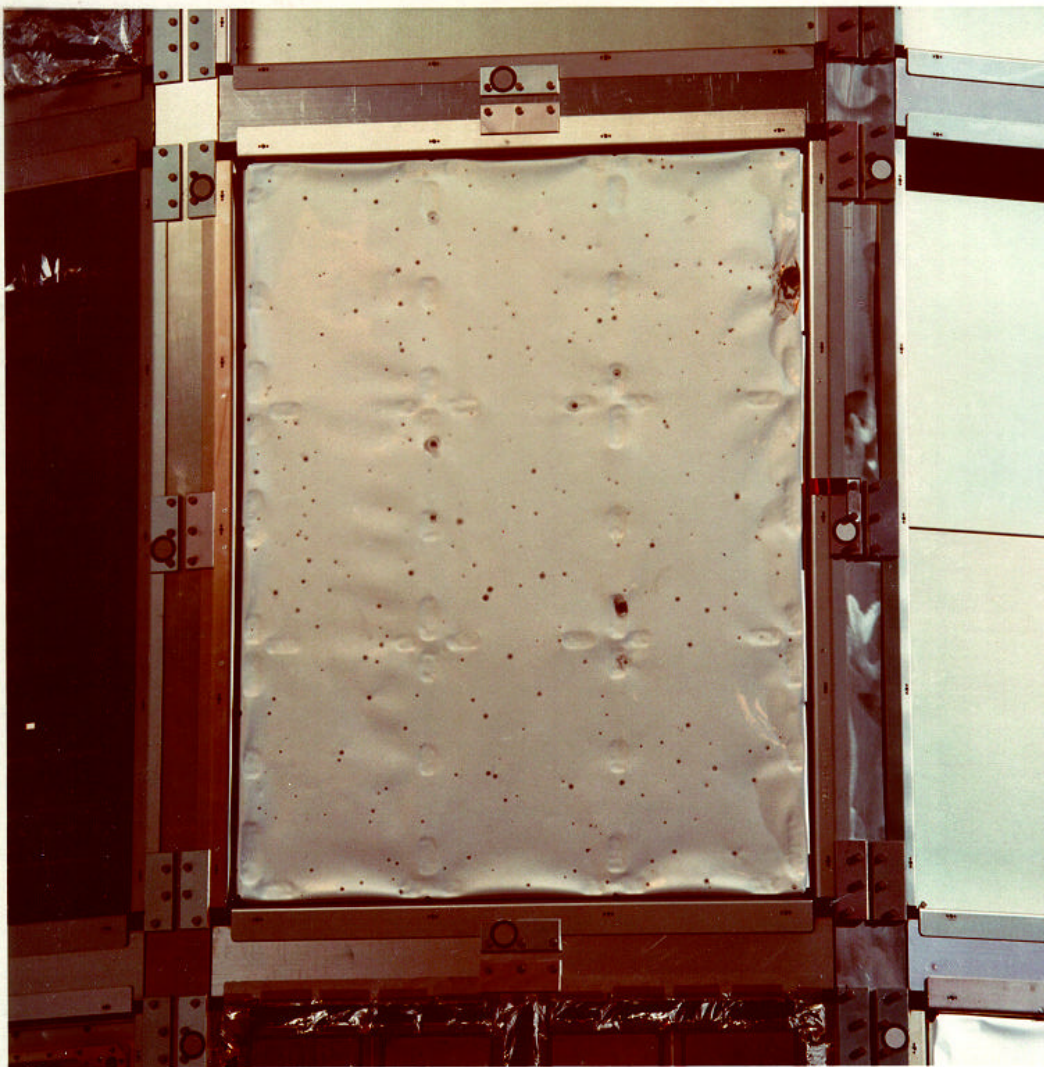
NASA On-orbit photo showing discoloration around vents on Interstellar Dust Experiment



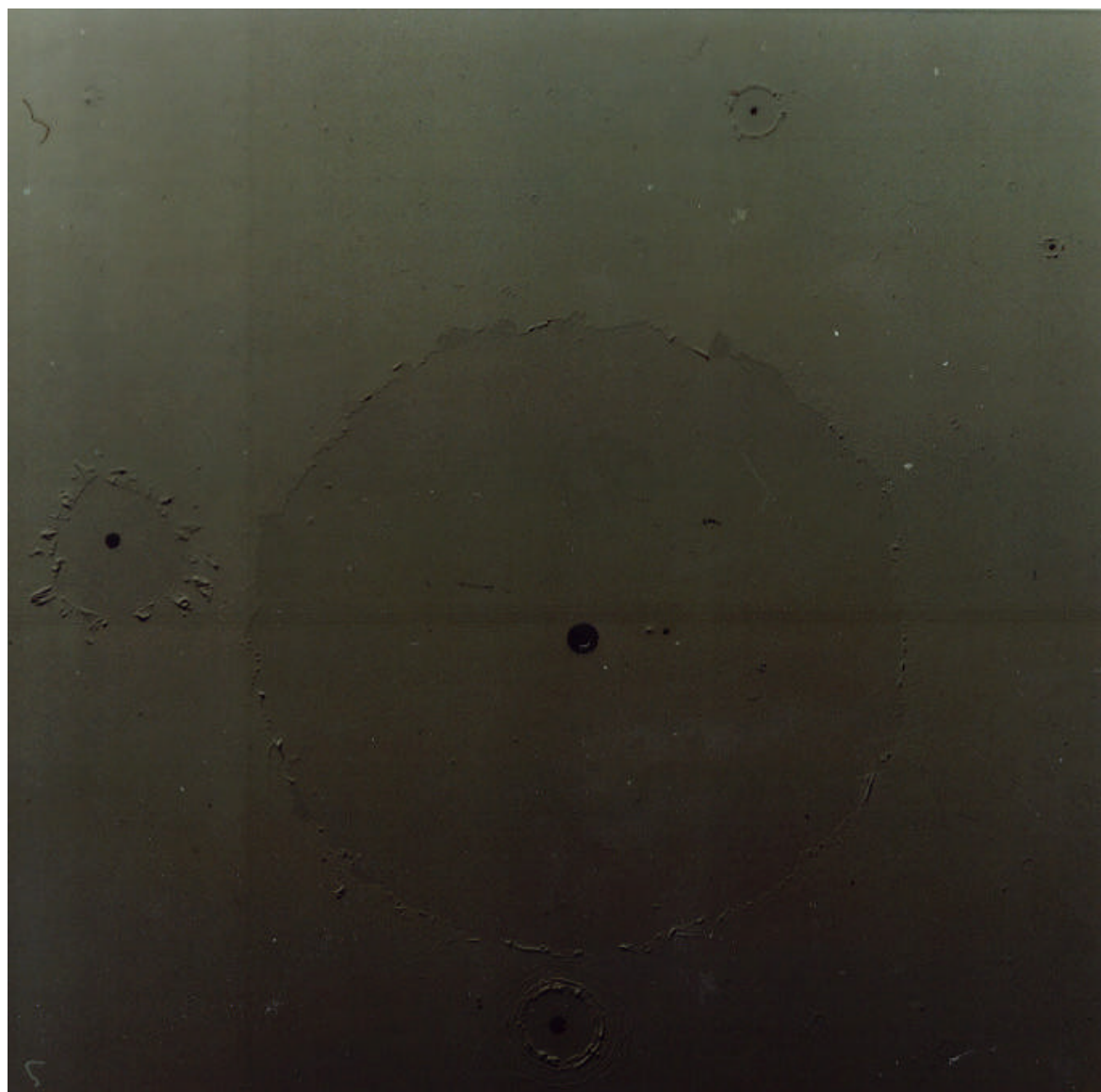
NASA On-orbit photo showing contamination around rivets and debris from mechanically failed hardware on right



Computer enhanced image showing LDEF wake contamination particles



NASA On-orbit photo showing impact damage on thermal control blanket



Close-up of impacts on painted aluminum surface from LDEF, NASA photo

Examples from other Flights

Re-Flights of LDEF Specimens

A276, Composite, Ag/FEP on EOIM III

Ag/FEP on ESEM

Beacon Radiators from Comstar

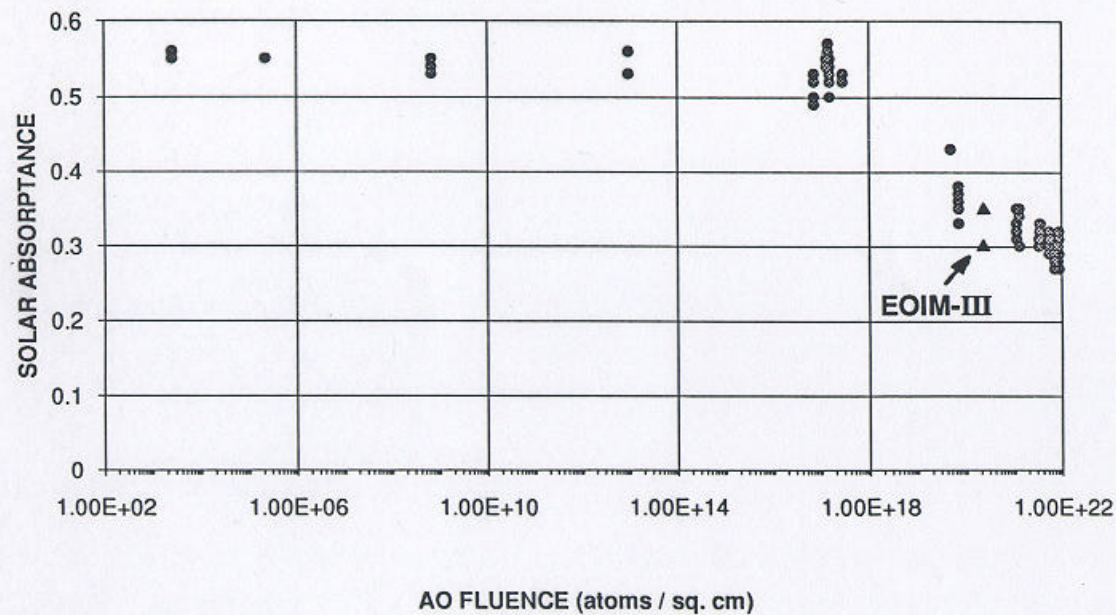
(N.L. Hyman, Comsat Technical Review, Vol 11, #2, Fall 1981)

1 radiator cleaned less than other due to pre-launch logistics priorities

Initial α for “less cleaned” radiator higher by ~0.01 absorptance units

Change in α over 6-month mission greater than “cleaner” radiator surface by ~0.01-0.02 absorptance units

SOLAR ABSORPTANCE VERSUS ATOMIC OXYGEN FLUENCE FOR LDEF SIDE TRAY A276 WHITE PAINT DISKS



EOIM-III Results Follow LDEF Trend



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While paint on MIR showing effects of multi-year exposure to space environment



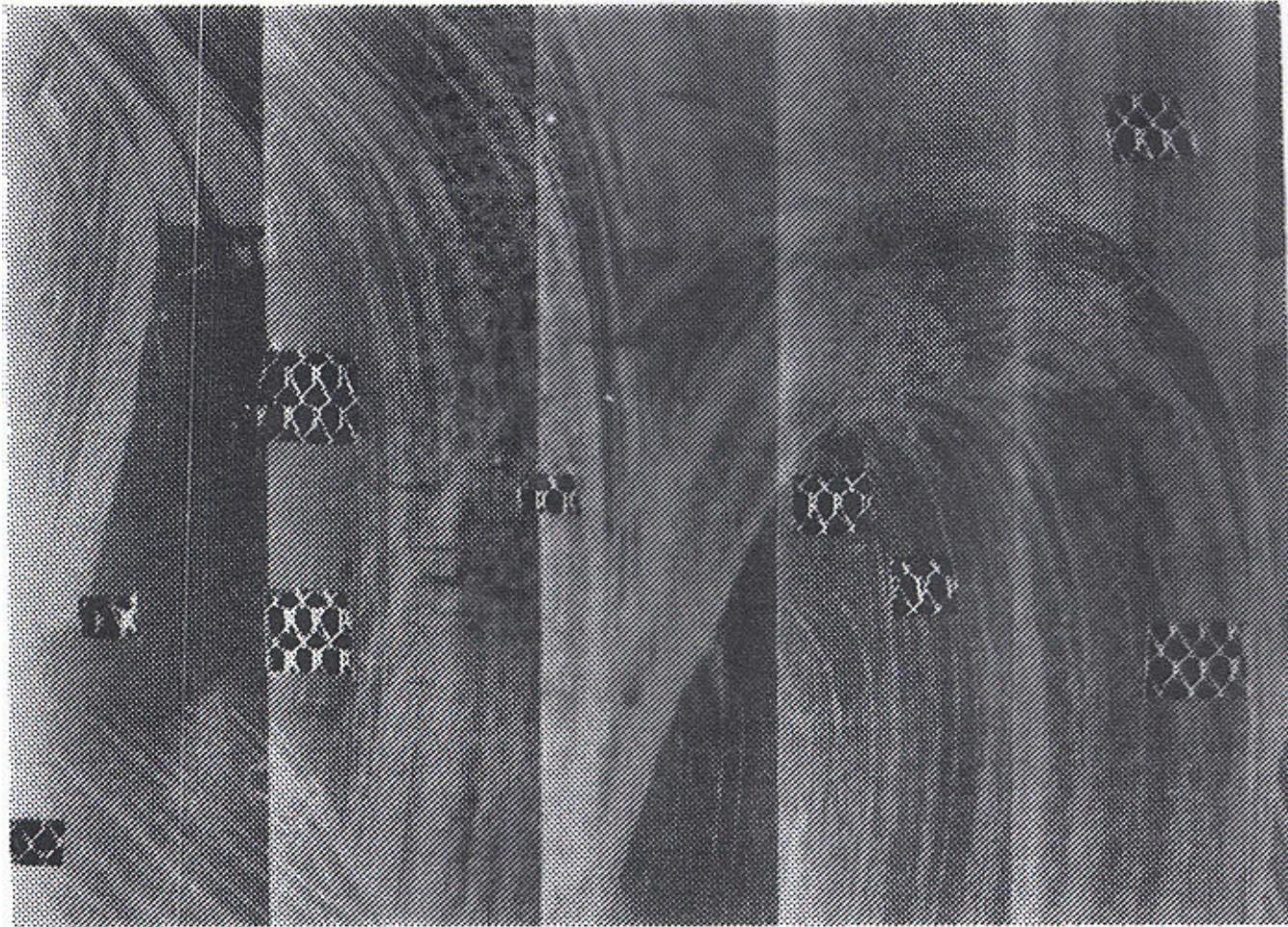
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NASA photo of MIR solar array panel showing impact damage at certain locations



NASA photo showing Kapton blanket retrieved from Solar Max satellite, wipe marks from attempted pre-flight cleaning are clearly visible



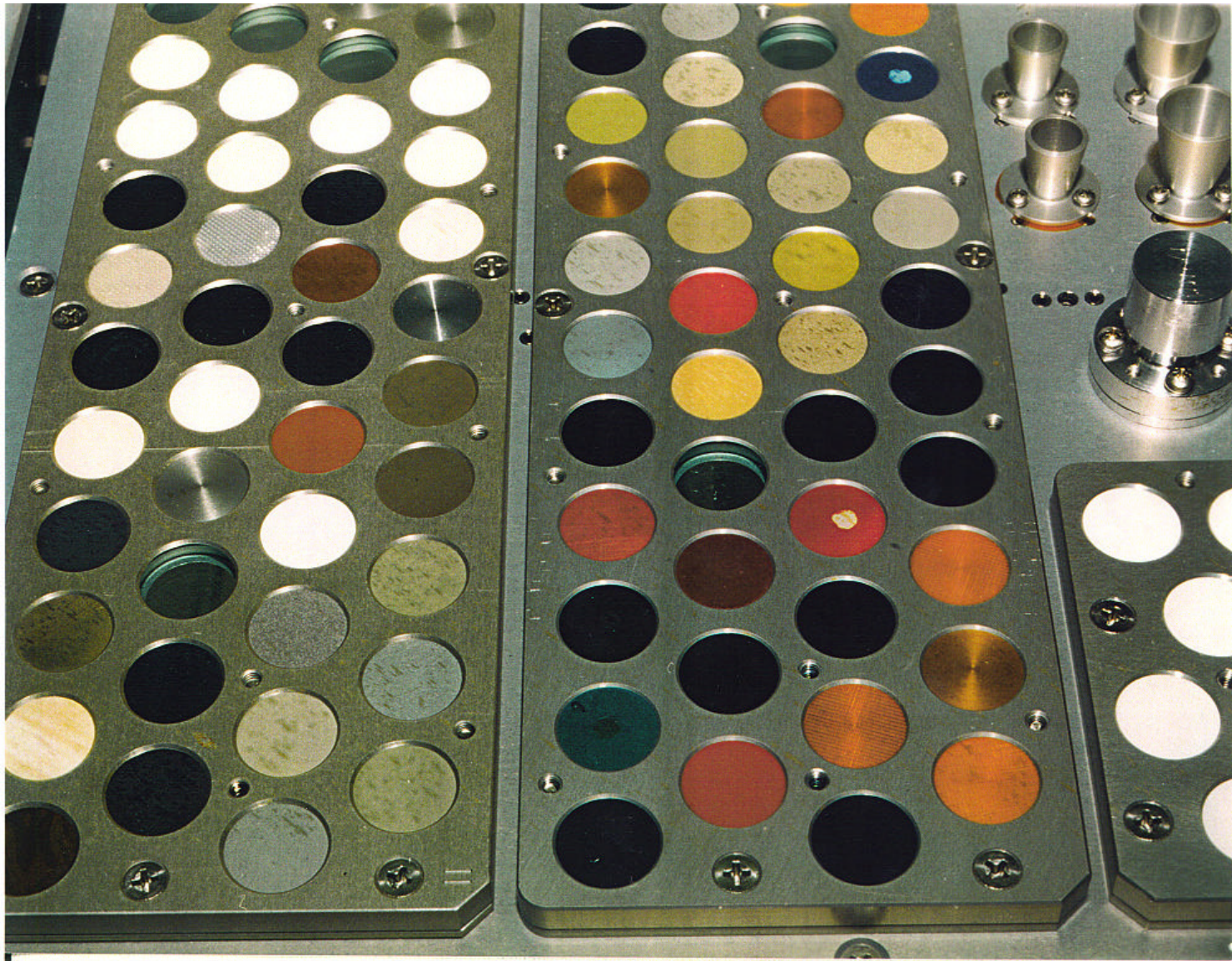
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NASA photo showing darkening around thruster cones on MIR



Close-up of part of POSA II experiment hardware showing visible contaminant streaks

LDEF Materials Lessons

**Inorganic thermal control paints, anodized aluminum, silverized teflon
Maintained a/e well – maintained thermal control function**

**Organic materials (Kapton, Mylar, paint binders, bare composites)
Showed expected severe recession and mechanical degradation under exposure
to atomic oxygen**

Coated composites maintained properties

Mechanically failed films produced low-density debris cloud on LDEF wake side

**Severely darkened contaminant deposits around vents from interior
“Line-of-sight” molecular contaminant films observed**

**M&D impacts on Ag/FEP blankets
Worst case compromised ~2% of area, delaminated ~5% of blanket area**

Additional Information Content from LDEF Hardware

Paints, thin films

UV induced polymeric cross-linking

Cannisters

Staged openings created varying deposition conditions

